COASTAL RESOURCES INVENTORY AND ENVIRONMENTAL SENSITIVITY MAPS: ALEUTIANS WEST COASTAL RESOURCE SERVICE AREA

INTRODUCTION

Environmental Sensitivity Index (ESI) maps have been developed for the coastal zone of the Aleutians West Coastal Resource Service Area (CRSA). The ESI mapping project was expanded to provide the basis for updating of the Coastal Management Program for this area. The ESI maps include information for three main components: shoreline habitats; sensitive biological resources; and human-use resources. In addition to the three traditional ESI components, general geothermal and mining resource information have been included on the maps, as well as locations of volcanic activity and faults. Background information, methods of data collection, and data presentation are summarized in the following sections.

SHORELINE HABITAT MAPPING

The intertidal habitats of the Aleutians West CRSA were mapped using two systems: the ESI shoreline ranking scheme and the Coastal Habitats shoreline ranking scheme. The two approaches are outlined below.

The shoreline of Unalaska Island was classified using the ESI ranking system during overflights conducted by an experienced coastal geologist on 30 June-3 July 2000. In the course of a typical ESI survey a combination of observational scales is employed. Prior to overflights, existing aerial photos and 1:63,360 topographic maps are examined and parameters such as tidal regime, wave energy, and long-shore sediment transport are assessed through interpretation of coastal landforms by a coastal geologist. If possible, modifications to the digital shoreline to be used in the project are made at this time. Overflights are then conducted, flying at altitudes ranging from 300 to 600 ft. and speeds of 80 knots. The timing of any ESI overflight is solely dependant upon the timing of the spring low tides. During a five hour interval of time centered on the peak low tide, a portion of the coast is flown and categorized in the terms of the ESI scale. Mapping only during this interval of time ensures the proper delineation of tidal flats and allows the maximum amount of the intertidal zone to be exposed and evaluated. ESI classifications are denoted directly onto 1:63,360 U.S. Geological Survey (USGS) maps. Additionally, small changes in the shoreline, such as inlet positions or new man-made structures, are drawn onto the basemaps. The final component of an ESI survey is the ground verification of the classifications made during overflights. Depending on logistics, representative examples of each ESI category are surveyed on the ground. In the case of Unalaska ground-truthing locations were: the north shore of Beaver Inlet near Ugadaga bay; Summer Bay; Iliuliuk Bay; Dutch Harbor; the northern and eastern shores of Amaknak Island, and Captains Bay. The maps used in the field are then digitized by teams of geographers and the digital shoreline is updated to reflect the observations made during the survey.

The shorelines of all other islands in the Aleutians West CRSA, from Attu to Umnak, were mapped at a scale of 1:250,000 by the same coastal geologist using the more general Coastal Habitat classification system. Overflights of these islands were not conducted, hence the separate mapping scheme. While interest remains high in conducting traditional field-oriented ESI surveys for these islands, budget considerations and logistical factors such as fuel staging, a short field season, habitation, and helicopter availability must be addressed. The mapping done in the Coastal Habitat classification scheme is based on field experience gained in the Unalaska mapping effort, National Imaging and Mapping Agency (NIMA) 1:25,000 topographic maps, USGS bulletin series 1028 (1951-1971) and local expertise. These classifications are not field checked. The categories in the Coastal Habitat scheme are similar to those included in the previous Aleutians West CRSA Resource Inventory atlas. However, the Coastal Habitat scheme improves on the previous work in that individual beaches are mapped as distinct coastal habitats.

SENSITIVITY INDEX (ESI) RANKING

Assessment of the environmental sensitivity of a particular intertidal habitat is based on an understanding of the dynamics of the coastal environments, not just the substrate type. The sensitivity ranking of a particular intertidal habitat is an integration of the following factors:

1) Shoreline type (substrate, grain size, tidal elevation, origin)
2) Exposure to wave and tidal energy
3) Biological productivity and sensitivity
4) Ease of cleanup (trafficability, permeability)

These concepts have been used in the development of the ESI, which ranks shoreline environments in terms of their relative sensitivity to oil spills. The original concept of ranking coastal environments on a scale of relative sensitivity was developed at Lower Cook Inlet in 1976 (Michel et al. 1978). Generally speaking, areas exposed to high levels of physical energy, such as wave action and tidal currents, rank low on the scale, whereas sheltered areas with associated high biological activity have the highest ranking. The key to the sensitivity ranking is an understanding of the relationships between: shoreline type; substrate; physical processes, sediment transport patterns; product type; and fate and effect of oil.

Since 1976, the ESI mapping scheme has been refined and expanded through repeated mapping and spill response experiences on most of the U.S. shorelines, including the Great Lakes. The result of these experiences is a standardized ESI shoreline habitat ranking system, consisting of 25 categories that encompass the general coastal habitats for the entire United States. This ranking system has been adopted by the National Oceanic and Atmospheric Administration and is a primary pollution response tool used by the United States Coast Guard (NOAA, 1997). In addition to the adoption of the ESI scheme by NOAA, the definitions of Environmentally Sensitive Areas (ESAs) as recorded in the Federal Register directly parallel the categories and concepts outlined in the ESI scheme (NOAA, 1994). These guidelines are commonly used for coastal zone management including: permitting, port development and management, and environmental assessment.

The ESI shoreline habitats delineated in this atlas are listed below in order of increasing sensitivity.

1A) Exposed Rocky Shores
2A) Exposed Wave-Cut Platforms in Bedrock
3A) Fine- to Medium-Grained Sand Beaches
4) Coarse-Grained Sand Beaches
5) Mixed Sand and Gravel Beaches
6A) Gravel Beaches
6B) Riprap
7) Exposed Tidal Flats
8A) Sheltered Rocky Shores
9A) Sheltered Tidal Flats
10A) Salt-and Brackish-Water Marshes

Each of the shoreline habitats are described on pages 9-12 in terms of their physical characteristics, predicted oil behavior, and response considerations.

COASTAL HABITAT MAPPING

The Coastal Habitat mapping scheme is based on the same factors and principles as the ESI mapping system but, because it is not a field survey based mapping scheme, provides less resolution. The Coastal Habitat categories and the corresponding ESI shorelines or shoreline combinations included within them are as follows:

1) Exposed Rocky Shores With or Without Wave Cut Platforms

   ESI = 1A, 1A / 2A

2) Exposed High Energy Shoreline (unidentified cliffs, platforms, and beaches)

   ESI = 1A, 1A / 2A, 1A / 5, 1A / 6A, 2A, 5, 6A

3) Beaches (fine and medium sand, coarse sand, sand and gravel, gravel)

   ESI = 3A, 4, 5, 6A

4) Exposed Tidal Flats

   ESI = 7

5) Estuarine Vegetation and Sheltered Coast

   ESI = 8A, 9A, 10A, 10A / 9A, 8A / 9A, 8A / 10A, 8A / 10A / 9A

It should be noted that Coastal Habitat #2, Exposed High Energy Shoreline, being the least specific of the five, was used only when data available would not permit identification of specific habitats.

The descriptions, response considerations, and photos of the ESI types on pages 9-12 should be consulted when using the Coastal Habitat maps.

SENSITIVE BIOLOGICAL RESOURCES

Biological information presented in this atlas was collected and compiled with the assistance of biologists primarily from the U.S. Fish and Wildlife Service, Alaska Department of Fish and Game, and National

Marine Fisheries Service, as well as other state and federal agencies and individuals. Information collected and depicted on the maps denotes the key biological resources that are most likely at risk in the event of an oil spill. Five major categories of biological resources are included in this atlas: marine mammals, birds, fish, submersed aquatic vegetation, and invertebrates.

Spatial distribution of the species on the maps is represented by polygons and points, as appropriate. Associated with each of these representations is an icon depicting the types of species or habitat types that are present. Species have been divided into groups and subgroups, based on their behavior, morphology, taxonomic classification, and vulnerability and sensitivity to impacts. The icons reflect this grouping scheme. The groups are color coded, and the subgroups are represented by different icons:

The polygon or point color and pattern are generally the same for all the species in each major group (e.g., birds are green), and match the icon colors. Species with a red box outlining the icon are listed as threatened or endangered at either the state or federal level. Also associated with each biological polygon or point feature on the map is a resources at risk identification number (RAR#), located under each icon or group of icons. The RAR# is the link to a table on the reverse side of the map with a complete list of species found in the polygon or at the point, as well as the state and federal protected status (T&E), concentration or abundance, seasonality, and life-history information for each species.

There are some species that are found throughout specific geographical areas or habitat types. Displaying the polygons for these species would cover large areas, making the maps very difficult to read. Thus, species which occur over the majority of certain geographic areas or habitats are often identified in a small box on the maps that states that they are “Present in ...” (e.g., “Present in Izembeck Lagoon”). This approach informs the user of the presence of these species, while maintaining readability of the map. In all instances, data for species listed as “Present in ....” exist as polygons in the digital coverages. The use of this strategy is implemented on a map per map basis, depending on the location, size, and number of polygons present on each map.

For many biological resources, information and expert knowledge may not be available for all geographic locations. For this reason, absence of a resource on a map does not necessarily mean it is not present. Under the descriptions of the various biological resource groups, the geographical limits of available knowledge or the survey boundaries of particular studies are given when known.

MARINE MAMMALS

Marine mammals depicted in the Aleutians West atlas include seals, sea lions, fur seals, walruses, and sea otters. Major haul-out sites for harbor seals, Steller sea lions, and northern fur seals, are depicted. Though only haul-out sites are mapped, seals can occur throughout the nearshore waters. For sea otters, concentration areas are shown where surveys have been conducted. Sea otters are present all year along the Aleutian Islands. Though not depicted on the maps, whales are highly mobile species, and they can occur throughout most of the waters. Gray whales are most commonly found in the migration corridor through Unimak Pass.

Many of the whales are listed as threatened or endangered species, and all marine mammals are protected under the Marine Mammal Protection Act of 1972. Sea Otters in the Aleutians are a candidate species for listing under the Endangered Species Act. Northern fur seals are currently listed as depleted under the Marine Mammal Protection Act.

Expert contacts for marine mammals in the Aleutians are the NMFS National Marine Mammal Lab, Seattle Washington; Brad Smith, NMFS, Anchorage, Alask; and USFWS Marine Mammals Management, Anchorage, Alaska.

Marine mammal concentration areas are displayed on the maps as polygons with a brown hatch pattern. If multiple resource types (marine mammals and birds) occupy the same polygon, a black-hatched multi-group pattern is used. A brown icon with a pinniped or whale silhouette is used to indicate the presence of marine mammals. The RAR# under the icon links to a table on the reverse side of the map. In this table, the first column gives the species name. The second column denotes whether the species has been designated as being endangered (E) or threatened (T) on either the state (S) and / or federal (F) lists. The next column provides an estimate of the concentration of the species at the site. Concentration is indicated as “HIGH”, “MODERATE”, or “LOW”, or numeric values are used for seal and sea lion haul-out sites. The species seasonality is shown in the next twelve columns, representing the months of the year. If the species is present at that location in a particular month, an “X” is placed in the month column. The final columns list the time periods for sensitive life-history stages or activities, such as pupping and molting for seals.

BIRDS

Birds are divided into several species subgroups based on taxonomy, morphology, behavior, and oil spill vulnerability and sensitivity. The species table lists all the birds included on the maps, sorted by subgroup. The major types of bird areas depicted in this atlas include: resident, migratory, nesting, and overwintering waterfowl concentration areas; migratory shorebird concentration areas; seabird concentration areas; and colonial waterbird nesting sites (for seabirds and wading birds).

Although birds are a major resource shown on the Aleutians West ESI maps, seabirds concentration areas are shown only where surveys have been conducted. Seabird nesting site information was obtained from the Beringian Seabird Colony Catalog database. The points representing the location of the nesting colonies are usually located near the geographic center of the colony. In some cases the point is located in the middle of an island, even though birds nest along the shorelines all around the island, not necessarily in the middle of the island. Waterfowl concentration areas shown on the map are derived from survey data provided by Alaska Department of Fish and Game, U. S. Fish and Wildlife Service, and local experts. Present but not shown are scattered distributions of emperor geese and Steller’s eider around the islands of the Western Aleutians. Data were also incorporated from Audubon Society Christmas bird counts. Eagle nest sites are found throughout the coastal zone of the Aleutians, however, because a comprehensive nest survey has not be conducted nesting sites are not shown. Eagles are present all year, but their most critical time is from March to August when they are nesting.

Expert contacts for birds are in the U.S. Fish and Wildlife Service, Refuge and Migratory Bird Management Divisions and ADF&G Habitat and Restoration Division.

Bird concentrations, including nesting areas for some species, are shown on the maps as polygons with a green hatch pattern. If multiple resource types (marine mammals and birds) occupy the same polygon, a black-hatched multi-group pattern is used. A green icon with the appropriate bird silhouettes (wading bird, raptor, etc.) is associated with the polygons. Seabird nesting sites from the U.S. Fish and Wildlife Service are shown with a green dot scaled to reflect the colony size. The RAR# under the icon links to a table on the reverse side of the map. In this table, the first column gives the species name. The second column indicates whether the species is listed as threatened (T) or endangered (E) on either the state (S) and / or federal (F) lists.

The next column in the tables provides an estimate of the concentration of each species at the site. Concentration is indicated as a numerical value representing the number of breeding pairs occurring at a nesting site, or as HIGH, MEDIUM, and LOW to represent relative concentrations. “Unknown” is used where the birds have been surveyed but an accurate count was not available. A blank field in concentration indicates no concentration information was provided. Nesting concentrations at any particular site may fluctuate seasonally and annually based on local or regional conditions, or other factors.

The species seasonality is shown in the next twelve columns representing the months of the year. If the species is present at that location in a particular month, an “X” is placed in the month column. The last columns denote the nesting period for each species, if nesting occurs in the particular area or site. Nesting refers to the entire nesting period, including laying, hatching, and fledging. For many species, there is a temporal shift in seasonality and reproduction along with spatial changes in location. Temporal information included in the tables is specific to the one polygon or point that it references.

FISH

The fish depicted in the Aleutians West ESI atlas include commercially important benthic and pelagic fish, herring spawning grounds, and streams important to anadromous fish. Not all species of environmental, recreational, or commercial interest are depicted.

The anadromous streams shown on the map are from Alaska Department of Fish and Game database, Waters Important to Anadromous Fish. Species included in these streams are coho, chinook, chum, pink, and sockeye salmon, dolly varden, and cutthroat trout.

While all of the anadromous streams in the database are shown, some of them are represented as a straight line, connecting the beginning point and endpoint of the stream, because the actual stream was not digitized. It is also cautioned that although this dataset is the best current representation of anadromous streams, it should not be considered definitive in determining the presence or absence of fish runs. Absence of anadromous streams on the maps for any particular location does not necessarily suggest that anadromous runs do not occur there.

Expert contacts for anadromous fish are in the ADF&G Habitat and Restoration Division.

Fish concentrations are shown on the maps as polygons with a blue hatch pattern. If multiple resource types (birds and fish) occupy the same polygon, a black-hatched multi-group pattern is used. A blue icon with a appropriate fish silhouette is associated with the polygons containing fish.

For the anadromous fish streams, a blue line is used to mark the fish runs (in the mouth of the stream). A blue icon with a fish silhouette is associated with the line using a leader line.

The RAR# positioned under the fish icon links to a table on the reverse side of the map. In this table, the first column gives the species name. The second column denotes whether the species has been designated as being endangered (E) or threatened (T) on either the state (S) and / or federal (F) lists. Concentration information was not available and was left blank. Seasonality is listed by month with an "X" indicating the species presence in any particular month. The last columns indicate time periods for various life-history stages or activities (spawning, eggs, larvae, juveniles, and adults). For many species there is a temporal shift in seasonality and life-history along with spatial changes in location. Temporal information included in the tables is specific to the one polygon or site that it references.

INVERTEBRATES

King crab, tanner crab, and dungeness crab can be found throughout the island chain. Depicted on the maps are the concentration areas for these species. These data were obtained from the National Marine Fisheries Service Essential Fish Habitat (1999) report.

Bivalve concentrations are also shown on the maps in some of the sheltered bays. While not depicted everywhere, it can be expected to find clam concentrations in the areas that have high waterfowl concentrations, since the clams are a principle food of the waterfowl.

Crab and bivalve concentrations are shown on the maps as polygons with an orange hatch pattern. If multiple resource types (crabs and fish) occupy the same polygon, a black-hatched multi-group pattern is used. A orange icon with a crab silhouette is associated with the polygons representing the distribution of crab.

The RAR# positioned under the crab icon links to a table on the reverse side of the map. In this table, the first column gives the species name. The second column denotes whether the species has been designated as being endangered (E) or threatened (T) on either the state (S) and / or federal (F) lists. Concentration information is given as "Minor", "General", or "Significant". Seasonality is listed by month with an "X" indicating the species presence in any particular month. The last columns indicate time periods for various life-history stages or activities (spawning, eggs, larvae, juveniles, and adults). For many species there is a temporal shift in seasonality and life-history along with spatial changes in location. Temporal information included in the tables is specific to the one polygon or site that it references.

SEAGRASSES

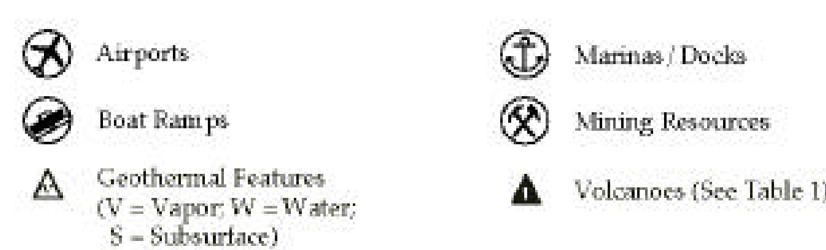
Eelgrass beds can be found throughout much of the island chain. The highest densities of beds are in the sheltered bays, however eelgrass is also found in the open coastal waters around the islands. Eelgrasses are only mapped in the areas where they have been reported as being present, but they likely exist through out the chain, scattered along the shorelines of all of the islands.

Eelgrass concentrations are shown on the maps as polygons with a purple hatch pattern. If multiple resource types (eelgrass and birds) occupy the same polygon, a black-hatched multi-group pattern is used. A purple icon with a eelgrass silhouette is associated with the polygons representing eelgrass.

The RAR# positioned under the eelgrass icon links to a table on the reverse side of the map. In this table, the first column gives the species name. No seagrasses are designated as Threatened or Endangered. The second column is blank. Concentration information is given as "High", "Abundant", "Present" and "Scattered".

HUMAN-USE FEATURES

The human-use features depicted on the maps are listed below. All the features are represented by icons indicating the type of human-use resource.



Airport—Location of airports, airfields, landing strips, etc., whether they are manned or unmanned. These sites were mapped during the overflights, and obtained from a state database of airports.

Boat Ramps—Location of boat ramps. This information was gathered via overflight observations, and from expert sources.

Geothermal Features—Geothermal resources categorized by dominate type (water, vapor, subsurface) as listed in Motyka et al. 1993.

Marina—Location of marinas and anchorages. This information was gathered via overflight observations, digital data, and expert sources.

Mining Resources—Location of known mineral resources, from the USGS Alaska Resource Data File.

Volcanoes—Locations of Quaternary volcanic activity. Main calderas and satellite vents as tabulated in Motyka et al. 1993.

GEOTHERMAL RESOURCES

The Aleutian Islands Arc, being the product of long-term and on-going volcanism, is rich in geothermal resources. The most recent compilation of the geothermal resources of the Aleutians was produced by Motyka et al. (1993) and was the primary source of geothermal information included in this atlas.

The geothermal resources of the Aleutians are all ultimately hydrothermal, that is, heat is transported by convective circulation of fluids within the subsurface as opposed to conduction through rock (Motyka et al. 1993). The primary styles in which geothermal activity is expressed at the surface can be grouped into three general categories: vapor-dominated sites, exposed geothermal waters, and subtle subsurface indicators. Vapor-dominated sites include fumaroles, superheated fumaroles, and gas vents. These are shallow vapor-dominated systems linked to deeper hot-water systems. True vapor-dominated sites are rare (Motyka et al., 1993). Exposed geothermal water sites include hot springs (T>50°C), warm springs (T<50°C), mud pots, geysers, and crater lakes. The last category, subtle subsurface indicators, consists of zones of steaming ground and geothermal wells. Steaming ground is included in this category because it is an expression of geothermal activity that is more dependent on surface saturation and vaporization of meteoric waters than on outgasing directly from deeper hydrothermal sources. Geothermal wells are simply artificial test wells drilled for the assessment of hydrothermal water temperatures and chemical composition.

Each geothermal site has been mapped according to the dominant style of geothermal activity. It is important to note that at any given site a combination of vapor, water, and subtle indicators of subsurface geothermal activity is most likely present. Geothermal sites appear on the maps as a yellow triangle containing a V, if vapor dominated; W, if water dominated; or S if the site is marked by only subtle indications of subsurface geothermal activity.

MINING RESOURCES

Exploited and unexploited mineral resources of the Aleutians include gold, silver, copper, iron, and titanium ores. Concentrations of sulfur and molybdenum are also present at some localities. The mineral commodities of the Aleutians are mapped using data from the USGS Alaskan Resource Data File (ARDF). Both potential and confirmed resource sites are included as points on the maps. Each point is labeled with a traditional pick and shovel accompanied by a number. The number below the pick and shovel symbol corresponds with a unique assemblage of resource elements found in the ore at that location. If no number exisits, the presence of a mining claim is known, but the resources or commodities being mined are not. The names of the individual minerals present at each site are not provided; only the significant economic elements of the ore are listed. A table on the back of each map lists the element assemblages present in the area. The elements are listed in the table on the back of the maps using their standard periodic table abbreviation as shown below:

Element	Description
Ag	Silver Ore Present
Au	Gold Ore Present
Cu	Copper Ore Present
Fe	Iron Ore Present
Hg	Mercury
Mo	Molybdenum
Pb	Lead Ore Present
S	Sulfur
Sb	Antimony
Ti	Titanium Ore Present
Zn	Zinc Ore Present

VOLCANOES OF THE ALEUTIANS ARC

Volcanism in the Aleutian Islands Arc is brought about by the ongoing subduction of the Pacific plate beneath the North American plate. As the oceanic crust of the Pacific plate migrates northwestward, it is overridden or subducted by the less dense crust of the North American plate. As the Pacific plate compresses, bends, and sinks beneath the North American plate, the pressure and temperatures increase greatly, converting solid rock into liquid magma. The magma, superheated and less dense than the material surrounding it, seeks a density equilibrium and rises towards the surface. These continuous tectonic processes have created the current assemblage of 89 Quaternary volcanoes distributed throughout the Aleutian chain. The natural and human development of each island in the chain has been and will continue to be affected by the eruptive capacity of these volcanoes.

Evaluation of the risk posed by individual volcanoes must take into account complex relationships between the size of an eruptive event and probability. These relationships are beyond the scope of this atlas. Suffice to say that a highly improbable large scale eruption will obviously have greater numbers of potentially destructive processes associated with it but, by nature of its improbability, pose a lower over- all risk than more probable smaller scale eruptive events. In the event of a small or large eruption, the following processes or volcanic hazards identified in Waythomas et al. (1998) and Beget et al. (2000), may exist; they are listed in relative order of importance:

Volcanic Ash Clouds. The primary hazard in eruptions of any size, these clouds of fine ash can reach heights of up to 20 kilometers or more above the volcano and can drift for thousands of kilometers down wind from their source. Presence of an ash cloud poses significant risk to cargo and passenger air transport and can cause total failure of jet engines. Prevailing winds tend to carry these clouds eastward.

Ash and Bomb Fallout. Ash fallout may occur within hundreds of kilometers down wind from the source. Bomb fallout occurs only within tens of kilometers of the volcano. Light ash fallout (millimeters of accumulation) can greatly reduce visibility (down to 100 meters) and cause respiratory complications in both humans and animals. Heavier accumulations (centimeters of accumulation) can interfere with electrical equipment and power generation and can cause roof collapse, in addition to intensifying complications associated with light volumes of fallout.

Lahars, Lahar Runout Flows, and Floods. Hot volcanic debris interacting with snow and ice at the summit or on the flanks of the volcano may form slurries of varying composition. Those dominated by mud and rock are classified as lahars. Those dominated by water are floods, and those with an intermediate mix are called lahar runout flows. Lahars and related flows are typically restricted to valleys and drainages and are a hazard to only those in their direct path. Lahars can travel upwards of 20 kilometers within a valley and move at speeds approaching 30 km per hour.

Pyroclastic Flows and Surges. Consisting of extremely hot material traveling down the flanks of the volcano, pyroclastic flows are a risk only to those in their path. Like all gravity driven flow. They will seek the lowest ground, and hence, tend to concentrate in valleys. Typically they travel no further than 10-15 km from the source

Debris Avalanche. These are rapidly moving (tens to hundreds of meters per second) masses of rock debris produced by large-scale landslides typically within a 10-15 km radius of the summit region. The direct hazard of a debris avalanche is typically limited to a volcano's flanks and valleys.

Directed Blasts. These are laterally directed explosions caused by the release of extremely high internal pressure during slope failure. While extremely rare, they are highly destructive with damage occurring up to 30 km away from the volcano.

Phreatomagmatic Explosions. Characterized by repeated explosions, ejection of bombs, and possible pyroclastic surges, these types of explosions occur near the volcano summit or near any satellite vents. They are caused by the rapid transition of water to steam which occurs when magma contacts surficial snow and ice.

Volcanic Gases. Dangerous odorless gases such as carbon monoxide and carbon dioxide may collect in and displace oxygen from low-lying areas near the summit or near any fumaroles. As such, the risk posed by gases is a localized one. In addition, highly detectable gases such as hydrogen sulfide and sulfur dioxide may be present. Aerosols or droplets of sulfuric acid may also be present in the air during eruptive events, causing corrosion of metals.

Lava Flows. Typical lava flows in the Aleutians arc are of andesitic or basaltic composition. As such they are not rapid moving flows (tens of meters per hour) and pose little risk to human life. Immobile structures in their path will be destroyed. Commonly the shedding of material down slope off the front of a flow or frontal lahars poses a large hazard than the flow itself. Lava flows tend to follow existing drainages and valleys.

The volcanoes of the Alaskan Peninsula and Aleutians Arc are monitored by the Alaskan Volcano Observatory (AVO). Weekly reports produced by the AVO update the "Level of Concern Code" status for each of the volcanoes under observation. The reports, available free at the AVO web site http://www.avo.alaska.edu/, are distributed to the Federal Aviation Administration, the National Weather Service, and the Alaska Department of Emergency Services.

Table 1 is a compilation of the volcanoes included on the maps of this atlas. Volcanoes are portrayed by a black triangle centered on the latitude and longitude of the primary peak. Each volcano is also labeled with a number corresponding to those shown in Table 1, which includes specific volcano names, volcano morphology or type, eruptive history, and general geothermal resource potential.

TABLE 1. VOLCANOES OF THE ALEUTIANS WEST CRSA.

No.	Volcano Name	Current Morphology[a]	Elev. (m)	Events Since 1760	Geothermal Potential	Map Number
1	Buldir	Strato-P	656	0	Poor	8
2	East Cape	Strato-P	610	0	Poor	8
3	Kiska	Strato	1,220	6	Fair	8
4	Segula	Strato	1,160	0	Fair	8
5	Little Sitkin	Strato-S	1,174	3	Good	7
6	Semisopochnoi	Shield-S,P	850	7	Fair	7
7	Gareloi	Strato-P	1,573	14	Fair	6
8	Sajaka	Strato	1,304	0	Fair	6
9	Tanaga	Strato	1,768	4	Fair	6
10	Takawangha	Strato	1,449	0	Fair	6
11	Bobrof	Strato	738	0	Poor	6
12	Kanaga	Strato	1,313	12	Fair	6
13	Moffett	Strato-P	1,196	0	Fair	6
14	Adagdak	Strato-P	610	0	Poor	6
15	Great Sitkin	Strato-P	1,750	11	Good	5
16	Kasatochi	Strato	314	3	Fair	5
17	Koniuji	Strato	273	0	Poor	5
18	Korovin	Strato-P	1,533	7	Fair	5
19	Kluichef	Strato-P	1,451	1	Good	5
20	Konia	Strato	1,125	0	Poor	5
21	Sarichef	Strato	610	1	Fair	5
22	Seguam (Pyre Peak)	Strato-P	1,054	9	Fair	4
23	Seguam East	Strato-P	854	0	Fair	4
24	Amukta	Strato	1,067	5	Fair	4
25	Chagulak	Strato	1,142	0	Poor	4
26	Yunaska	Strato-P	610	5	Fair	4
27	Herbert	Strato	1,280	0	Poor	3
28	Carlisle	Strato	1,620	4	Poor	3
29	Cleveland	Strato	1,730	12	Fair	3
30	Uliaga	Strato	888	0	Poor	3
31	Chuginadak East	Strato	1,170	0	Poor	3
32	Kagamil	Strato	893	12	Fair	3
33	Vsevidof	Strato-P	2,134	4	Fair	3
34	Recheshnoi	Strato-P	1,984	0	Good	3
35	Okmok	Shield-S,P	1,072	18	Fair / Good	3
36	Bogoslof	Dome Complex	44	12	Poor	3
37	Pakushin Cone	Strato	1,035	0	Poor	1
38	Makushin	Shield-S	2,036	20	Confirmed	1
39	Table Top Mountain	Strato	792	0	Poor	1
40	Wide Bay Cone	Strato	610	0	Poor	1

[a] The primary terms used in the description of volcanic morphology are defined as follows:

Strato: Stratovolcanoes are composed of both volcanic flows and ejected tephra and pyroclastics. The majority of the Aleutian volcanoes are of this type.

Shield: Shield Volcanoes are typically gently sloping, broad volcanoes composed solely of basaltic lava flows.

Dome: In some cases synonomous with shield, this term can also pertain to steeper sided protrusions of viscous lava on the flanks of larger shield volcanoes

Maar: A low relief, broad volcanic crater formed by multiple shallow explosive eruptions.

P: Indicates the presence of smaller cones or vents on the flanks of the volcano.

S: Indicates that larger satellite volcanoes occur on the flanks of the volcano

[b] The elevations listed here are the highest recorded points on each volcano. When a large caldera rim is present the actual eruptive center of the volcano may be at a lower elevation

(after Motyka et al., 1993)

There are forty volcanoes in or just adjacent to the Aleutians West Coastal Resource Service Area. Nine of these are found in the Islands of Four Mountains, including one of the more recently active volcanoes, Mt. Cleveland. In its twelfth historically recorded event Mt. Cleveland erupted on February 19th, 2001. The blast was preceded by just over two weeks of calm lava flows near the summit. The first eruptive phase was followed by two others on March 11 and 19. An ash cloud from the initial eruption extended 35,000 feet into the air, spreading over the next two days as far east as Anchorage. The island of Nikolski to the east of Mt. Cleveland experienced significant ash fallout. Since 1760 the volcanoes of the western Aleutians have produced a total of 170 recorded eruptive events. Over this period, the most active volcanoes in the area have been Gareloi, Okmok, and Makushin.

FAULTING AND SEISMIC HAZARDS IN THE ALEUTIANS ARC

Another geophysical hazard caused by the subduction of the Pacific plate beneath the North American plate is earthquakes. To accommodate the tremendous stress and strain associated with the collision of the two plates, each will deform. This deformation is expressed in several ways. Some of the deformation is ductile, during which rocks are heated and compressed at rates that allow the minerals within them to re-organize their crystal structures or metamorphose. Ductile deformation usually occurs at great depths and may result in intensification of mineralization. Another way deformation associated with the collision is expressed is through brittle deformation or fracturing of the rock. This usually occurs at shallower depths than ductile deformation and may be expressed on the surface as faulting. Each type of deformation is continuously driven by subduction. The interface between tectonic plates is an extremely complex area. Stresses can build in one location while motion continues in another. Eventually, stresses reach a critical threshold and the stored energy is released resulting in an earthquake. The seismic energy released by these earthquakes can create new brittle deformation in the rocks above and / or trigger localized motion on existing fault planes. The Aleutian Islands, which owe their existence to the subduction of the Pacific plate, are also one of the most active seismic zones on the planet because of it.

The subduction and subsequent bending of the Pacific plate has created a bathymetric depression offshore that runs roughly parallel to the southern coastline of the Aleutian Islands. This area is called the Aleutian Trench and most of the earthquakes of the region have their origins (epicenters) near it.

Since 1963 there have been as many as 2403 Richter scale magnitude 5 or higher earthquakes along the Aleutian Island Arc and Alaskan Peninsula. Only 101 have been magnitude 6 or higher (Haberman, 2000). While seismic activity at magnitudes 5 and higher generally cause damage, it is impossible to generalize a relationship between earthquake magnitude and the risk or hazard the event poses to humans. Many local factors must be taken into account. Soil type, hydrology, and local slope, all differ from site to site and all effect the amount of damage an earthquake may cause. In a seismically active area risk is perhaps best assessed in terms of the amount of human infrastructure there is to lose. For example, despite the fact that both California and the Aleutians are seismically active areas, it could be said that earthquakes are a bigger hazard in California simply by virtue of a greater population density.

In the Aleutians West CRSA, 62 of the 101 magnitude 6 or higher earthquake epicenters (Haberman, 2000). Many were located south of the area shown on the maps in this atlas. These 62 events occurred between 1965 and 1999. Of note due to their epicentral proximity to land are the following earthquakes:

A. 9 km west of Kashega village, Unalaska, magnitude 6, 1987

B. 12 km west of Cape Star, Umnak, magnitude 6.3, 1999

C. Seven quakes, just west of Ulak Pass in Delarof Islands, magnitude 6-6.4, 1969-1997

D. Six quakes, on and southeast of Amchitka Island, magnitude 6-6.8, 1965-1997

Faults on which movement may be triggered are portrayed on the maps by a bold red line.

TSUNAMIS

The term Tsunami applies to impulsively (as opposed to meteorologically) generated gravity waves in water. They can be produced in three ways: 1) uplift or drop of a large area of the ocean floor during earthquakes; 2) subaerial or submarine landslides or, 3) events linked to volcanism (Lander, 1996). Volcanically induced tsunamis are controversial in that it is difficult to definitively link a tsunami to a volcanic event.

It is a common misconception that tsunamis are always towering waves breaking and plunging landward. While some rare tsunamis do reach those proportions, most are perceived as a rapid rise and fall of the "tide", hence the commonly used and incorrect term "tidal-wave". The character of a tsunami event will vary with the source type, but all tsunamis move at extremely rapid rates (speeds up to and above 500 miles per hour) and ultimately the generation of almost all tsunamis can be linked to zones of subduction such as the Aleutian Trench.

It is both important and interesting to note the directional nature of tsunamis and their hazard. Areas perpendicular to the source of the tsunami suffer the greatest effects, while those to the sides may feel no disturbance at all. When looking at a map, however, it is necessary to realize that a straight line on a sphere is a great circle route, hence the arcing appearance of published tsunami tracks. The directional nature of tsunamis is illustrated to some degree by the fact that tsunamis generated at the Aleutians Arc have caused 175 fatalities in Hawaii in addition to 19 on the mainland coast of the western U.S. This total is higher than all the tsunami related deaths in Alaska (122) (Lander, 1996). Low numbers of fatalities in on the Aleutian Islands and southern Alasakan Peninsula can be related to low population density and the tendency toward construction on the northern, sheltered coastlines.

Tsunamis, no matter what their source type, can be classified as either teletsunamis or local tsunamis. A teletsunami is simply one observed at distances greater than or equal to 1000 kilometers from its source. The source for a teletsunami must be an earthquake of significant size (typically above magnitude 6). In the case of any seismically generated tsunami, the source area can be quite large (on the order of 500 to 800 kilometers in length) despite the tendency to portray an earthquake epicenter as a point. The period of warning for a teletsunami may be on the order of hours to days, depending on source location. Teletsunamis are not a primary risk on the Aleutian Arc. Risk increases slightly to the west due to the proximity of the subduction zone off shore of Kamchatka and the indo-china trench. Local tsunamis, defined as a tsunamis generated adjacent to the shoreline, are a much greater risk to all of the Aleutians and Alaskan Peninsula, particularly along the southern shorelines. Local tsunamis are usually generated by lower energy sources such as landslides or volcanism. Warning periods for these events can be as small as a matter of minutes. The safest policy is that higher ground should be sought after any indication of earthquake activity.

Recorded instances of teletsunamis in the Aleutians are rare. In 1960, a 4.5 foot surge caused minor flooding in Massacre Bay and on the southern shores of Attu. This surge was caused by earthquake activity in Chile. Tsunami events of extremely small amplitude are regularly observed in Massacre Bay and are attributed to seismic events near Kamchatka and the Kuril Islands of Russia.

Instances of local tsunamis are more frequently recorded than teletsunamis, but events of significant size still remain relatively rare. Still, it should be noted that roughly 98 percent of all tsunami-related fatalities can be attributed to local events (Lander, 1996). The most significant seismically generated local tsunami occurred in 1946 when a magnitude 7.8 earthquake occurred roughly 144 kilometers off shore of Unimak Island. Reports indicate that roughly 45 minutes after the initial earthquake was felt a 100 ft. tsunami impacted the southern Unimak coast at Scotch Cap destroying a new lighthouse and resulting in five fatalities. Forty meters of run up (distance inland affected by the water) were recorded. Additionally, several homes on the eastern shore of Akutan were washed off their foundations (Waythomas, 1998). Since the 1946 event, ten seismically induced waves have been recorded along the Aleutians Arc. The lowest magnitude seismicity associated with these events was 6.5, and the only areas with minor flooding were the islands of Shemya and Amchitka.

Landslide generated tsunamis are most common in heavily glaciated regions such as southeastern Alaska. Large amounts of till and pro-glacial sediment loading deltas creates a greater chance for slope failure. There are no reports of tsunamis associated with landslides in the regions covered in this atlas. This is not to say these events are impossible in the region. In fact, for the more sheltered northern shorelines, these types of events most likely account for most of what little tsunami risk there may be.

Overall, the hazard posed by tsunamis in the study area is relatively low. On average 2 significant tsunami events per decade are recorded in all of Alaska (Lander, 1996). The southern shorelines have a much higher risk than northern shores due to their exposure to the Aleutians trench, a local seismic source, and their exposure to teletsunamis originating at the boundaries of the Pacific plate.

REFERENCES

Listed below are the major hardcopy reference materials used during this project. In some instances, reference materials were not directly used as source materials, but were instead used or interpreted by scientists or resource managers who provided expert knowledge or personal communication concerning resources depicted in the atlas.

Alaska Department of Fish and Game, 1984, Habitat Management Guide, Habitat Division, Anchorage, AK.

Aleutians Subarea Contingency Plan, 1999, Sensitive Areas Section.

Aleutians West Coastal Resource Service Area, 1990, Resource Inventory Atlas, Volume I, Aleutians West CRSA.

Aleutians East Coastal Resource Service Area, 1984, Resource Inventory for the Aleutians East Coastal Resource Service Area, Aleutians East CRSA.

Beget, J.E., C.J. Nye, and K.W. Bean, 2000, Preliminary Volcano-Hazard Assessment for Makushin Volcano, Alaska. Report of Investigations 2000-4, Alaska Department of Natural Resources Division of Geological and Geophysical Surveys; Alaska Volcano Observatory, Fairbanks, AK.

Byers, Jr., F.M., 1959, Geology of Umnak and Bogoslof Islands, Aleutian Islands Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-L, United States Government Printing Office, Washington, D.C.

Byrd, V.G., 1992, Status of Sea Ducks in the Aleutian Islands, Alaska. Report prepared for Sea Duck Workshop, Anchorage, Alaska. U.S. Fish and Wildlife Service.

Coats, R. R., 1959, Geologic Reconnaissance of Gareloi Island, Aleutian Islands, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-J, United States Government Printing Office, Washington, D.C.

Coats, R. R., 1959, Geologic Reconnaissance of Semisopochnoi Island, Western Aleutian Islands, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-O, United States Government Printing Office, Washington, D.C.

Coats, R. R., 1956, Geology of Northern Kanaga Island, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-D, United States Government Printing Office, Washington, D.C.

Coats, R. R., W. H. Nelson, R. Q. Lewis, and H. A. Powers, 1961, Geologic Reconnaissance of Kiska Island Aleutian Islands, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-R, United States Government Printing Office, Washington, D.C.

Drewes, H., G.D. Fraser, G.L. Snyder, and H.F. Barnett, Jr., 1961, Geology of Unalaska Island and Adjacent Insular Shelf, Aleutian Islands, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-S, United States Government Printing Office, Washington, D.C.

Fraser, G.D. and H.F. Barnett, 1959, Geology of the Delarof and Westernmost Andreanof Islands, Aleutian Islands, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-I, United States Government Printing Office, Washington, D.C.

Fraser, G.D. and G.L. Synder, 1959, Geology of Southern Adak Island and Kagalaska Island, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-M, United States Government Printing Office, Washington, D.C.

Gates, O., H. A. Powers, R. E. Wilcox, and J. P. Schafer, 1971, Geology of the Near Islands, Alaska, Investigations of Alaskan Volcanoes, Geological Survey Bulletin 1028-U, United States Government Printing Office, Washington, D.C.

Haberman, T., 2000, Personal communication and NOAA National Geophysical Data Center Website at: http://www.ngdc.noaa.gov/seg/hazard/earthqks.html.

Kennedy, G. C. and H. H. Waldron, 1955, Geology of Pavlof Volcano and Vicinity, Alaska, Investigations of Alaskan Volcanoes, Geological Survey Bulletin 1028-A, United States Government Printing Office, Washington, D.C.

Lander, J.F., 1996, Tsunamis Affecting Alaska 1737-1996. National Geophysical Data Center Key to Geophysical Research Documentation No. 31, 195 p.

Lewis, R.Q., W.H. Nelson, and H.A. Powers, 1960, Geology of Rat Island, Aleutian Islands, Alaska, Investigations of Alaskan Volcanoes.

Geological Survey Bulletin 1028-Q, United States Government Printing Office, Washington, D.C.

Michel, J., M.O. Hayes, and P.J. Brown, 1978, Application of an Oil Spill Vulnerability Index to the Shoreline of Lower Cook Inlet, Alaska. Environmental Geology, v.2 (2) pp. 107-117.

Miller, T.P., R.G. McGimsey, D.H. Richter, J.R. Riehle, C.J. Nye, M.E. Yount, and J.A. Dumoulin, 1998, Catalog of the Historically Active Volcanoes of Alaska. Open-File Report 98-582, U.S. Geological Survey, Anchorage, AK.

Motyka, Roman J., S.A. Liss, C.J. Nye, and M.A. Moorman, 1993, Geothermal Resources of the Aleutian Arc. Professional Report 114, Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys, Fairbanks, AK.

Murie, O.J., 1959, Fauna of the Aleutian Islands and Alaska Peninsula. No. Am. Fauna 61, Washington, D.C. 406 pp.

National Marine Fisheries Service, 1999, Essential Fish Habitat Assessment Report for the Groundfish Resources of the Gulf of Alaska Region. National Marine Fisheries Service, Anchorage, AK.

NOAA, 1994, Environmentally Sensitive Areas, 59 FR 14714.

NOAA, 1997, Environmental Sensitivity Index Guidelines, Version 2.0. NOAA Technical Memorandum NOS ORCA 115. Seattle: Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration, 79 pp.

Nelson, W.H., 1959, Geology of Segula, Davidof and Khvostof Islands, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-K, United States Government Printing Office, Washington, D.C.

Powers, Howard A., Robert R. Coats, and Willis H. Nelson, 1960, Geology and Submarine Physiography of Amchitka Island, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-P, United States Government Printing Office, Washington, D.C.

Research Planning Institute, Inc., 1985, Sensitivity of Coastal Environments and Wildlife to Spilled Oil, Southern Alaska Peninsula Atlas. Prepared for Outer Continental Shelf Environmental Assessment Program, Ocean Assessments Division, 61 Maps.

Research Planning Institute, Inc., 1981 Sensitivity of Coastal Environments and Wildlife to Spilled Oil, Bristol Bay Atlas. Prepared for Bureau of Land Management, Anchorage Alaska, and National Oceanic and Atmospheric Administration Outer Continental Shelf Assessment Program, Juneau, AK. 106 maps.

Simons, F.S., and D.E. Mathewson, 1955, Geology of Great Sitkin Island, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-B, United States Government Printing Office, Washington, D.C.

Synder, G.L., 1959, Geology of Little Sitkin Island, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-H, United States Government Printing Office, Washington, D.C.

Synder, G.L., 1957, Ocean Floor Structures, Northeastern Rat Islands, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-G, United States Printing Office, Washington, D.C.

U. S. Fish and Wildlife Service, 1999, Population Status and Trends of Sea Ducks in Alaska. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska.

U. S. Fish and Wildlife Service, 2000, Beringian Seabird Colony Catalog -- computer database. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska.

U.S. Geological Survey, Unknown, Alaska Resource Data File (ARDF) http://ardf.wr.usgs.gov/.

Waldron, H.H., 1961, Geologic Reconnaissance of Frosty Peak Volcano and Vicinity, Alaska, Investigations of Alaskan Volcanoes. Geological Survey Bulletin 1028-T, United States Government Printing Office, Washington, D.C.

Waythomas, Christopher F., Thomas P. Miller, Christina A. Neal, and Robert G. McGimsey, 1997, Preliminary Volcanic-Hazard Assessment for Pavlof Volcano, Alaska, Open-File Report 97-135, U.S. Geological Survey, Alaska Volcano Observatory, Anchorage, AK..

Waythomas, C.F., J.A. Power, D.H. Richter, and R.G. McGimsey, 1998, Preliminary Volcano-Hazard Assessment for Akutan Volcano East-Central Aleutian Islands, Alaska. Open-File Report 98-360, U.S. Geological Survey, Alaska Volcano Observatory, Anchorage, AK..

Wilson, F.H., W.H. White, R.L. Detterman, and J.E. Case, 1996, Maps Showing the Resource Assessment of the Port Moller, Stepovak Bay, and Simeonof Island Quadrangles, Alaska Peninsula. MAP MF-2155-F, U.S. Geological Survey.

ACKNOWLEDGMENTS

This project was supported by the Prince William Sound Oil Spill Recovery Institute, Gary Thomas, Director; the Aleutians West CRSA, Karol Kolehmainen, Program Director; the Aleutians East Borough, Sharon Boyette, Special Assistant; the Alaska Chadux Corporation, Robert Heavilin, General Manager; and the U.S. Coast Guard. Mary Stadum of The Stadum Group coordinated the work with the Aleutians West CRSA. John Whitney with the National Oceanic and Atmospheric Administration assisted with overall project coordination.

The biological and human-use data included on the maps were provided by a great many individuals within the U.S. Fish and Wildlife Service, Alaska Department of Fish and Game, Alaska Department of Natural Resources, National Forest Service, Alaska Department of Environmental Conservation and National Oceanic Atmospheric Administration, National Marine Fisheries.

At Research Planning, Inc. (RPI) of Columbia, South Carolina, numerous scientific, GIS, and graphics staff were involved with different phases of the project. Jacqueline Michel was the project manager. Shoreline habitat mapping and the compilation of geothermal, mineral resource, and seismic hazard information was conducted by Colin Plank. The biological and human-use data were collected by Jeffrey Dahlin. Mark White, Vermell Simon, Jennifer Rainman, and Katie Born entered the data and produced the final maps. Systems administration was conducted by William Holton. Graphics were provided by Joe Holmes.

SPECIES LIST*

MARINE MAMMALS

PINNIPEDS

Common Name	Species Name
Harbor seal	*Phoca vitulina*
Steller (Northern) sea lion	*Eumetopias jubatus*
Northern fur seal	*Callorhinus ursinus*

SEA OTTERS

Common Name	Species Name
Sea otter	*Enhydra lutris*

BIRDS

ALCIDS

Common Name	Species Name
Ancient murrelet	*Synthliboramphus antiquus*
Black guillemot	*Cepphus grylle*
Cassin's auklet	*Ptychoramphus aleuticus*
Common murre	*Uria aalge*
Crested auklet	*Aethia cristatella*
Horned puffin	*Fratercula corniculata*
Least auklet	*Aethia pusilla*
Murre	*Uria sp.*
Murrelets	-
Parakeet auklet	*Aethia psittacula*
Pigeon guillemot	*Cepphus columba*
Rhinoceros auklet	*Cerorhinca monocerata*
Thick-billed murre	*Uria lomvia*
Tufted puffin	*Fratercula cirrhata*
Whiskered auklet	*Aethia pygmaea*

DIVING BIRDS

Common Name	Species Name
Common loon	*Gavia immer*
Cormorant	*Phalacrocorax sp.*
Double-crested cormorant	*Phalacrocorax auritus*
Pelagic cormorant	*Phalacrocorax pelagicus*
Red-faced cormorant	*Phalacrocorax urile*

GULLS AND TERNS

Common Name	Species Name
Aleutian tern	*Sterna aleutica*
Arctic tern	*Sterna paradisaea*
Glaucous-winged gull	*Larus glaucescens*
Mew gull	*Larus canus*
Terns	-

PELAGIC

Common Name	Species Name
Black-legged kittiwake	*Rissa tridactyla*
Fork-tailed storm-petrel	*Oceanodroma furcata*

BIRDS

PELAGIC (cont.)

Common Name	Species Name
Leach's storm-petrel	*Oceanodroma leucorhoa*
Northern fulmar	*Fulmarus glacialis*
Red-legged kittiwake	*Rissa brevirostris*
Shearwaters	-
Storm-petrels	*Oceanodroma spp.*

SHOREBIRDS

Common Name	Species Name
Black oystercatcher	*Haematopus bachmani*
Rock sandpiper	*Calidris ptilocnemis*
Shorebirds	-

WATERFOWL

Common Name	Species Name
American wigeon	*Anas americana*
Black (common) scoter	*Melanitta nigra*
Brant	*Branta bernicla*
Bufflehead	*Bucephala albeola*
Canada goose	*Branta canadensis*
Common eider	*Somateria mollissima*
Common goldeneye	*Bucephala clangula*
Common merganser	*Mergus merganser*
Emperor goose	*Chen canagica*
Gadwall	*Anas strepera*
Greater scaup	*Aythya marila*
Green-winged teal	*Anas crecca*
Harlequin duck	*Histrionicus histrionicus*
King eider	*Somateria spectabilis*
Mallard	*Anas platyrhynchos*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Oldsquaw	*Clangula hyemalis*
Red-breasted merganser	*Mergus serrator*
Scoters	*Melanitta spp.*
Steller's eider	*Polysticta stelleri*
Surf scoter	*Melanitta perspicillata*
Tundra (whistling) swan	*Cygnus columbianus*
Waterfowl	-
White-winged scoter	*Melanitta fusca*

FISH

DIADROMOUS

Common Name	Species Name
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon (dog)	*Oncorhynchus keta*
Coho salmon (silver)	*Oncorhynchus kisutch*

FISH

DIADROMOUS (cont.)

Common Name	Species Name
Dolly varden	*Salvelinus malma*
Pink salmon (humpy)	*Oncorhynchus gorbuscha*
Rainbow trout (steelhead)	*Oncorhynchus mykiss*
Sockeye salmon (red)	*Oncorhynchus nerka*

ESTUARINE NURSERY

Common Name	Species Name
Pacific herring	*Clupea pallasi*

MARINE BENTHIC

Common Name	Species Name
Alaska plaice	*Pleuronectes quadrituberculatus*
Arrowtooth flounder	*Atheresthes stomias*
Flathead sole	*Hippoglossoides elassodon*
Greenland halibut (turbot)	*Reinhardtius hippoglossoides*
Pacific cod	*Gadus macrocephalus*
Pacific halibut	*Hippoglossus stenolepis*
Rock sole	*Lepidopsetta bilineata*
Sablefish (blackcod)	*Anoplopoma fimbria*
Walleye pollock	*Theragra chalcogramma*
Yellowfin sole	*Pleuronectes asper*

MARINE PELAGIC

Common Name	Species Name
Atka mackerel	*Pleurogrammus* monopterygius

INVERTEBRATES

BIVALVES

Common Name	Species Name
Blue mussel	*Mytilus edulis*
Macoma spp.	*Macoma spp.*
Pacific razor clam	*Siliqua patula*
Washington butter clam	*Saxidomus giganteus*
Weathervane scallop	*Patinopectin caurinus*

CRABS

Common Name	Species Name
Red king crab	*Paralithodes camtschaticus*
Tanner crab	*Chionoecetes bairdi*

PLANTS

SAV

Common Name	Species Name
Eelgrass	*Zostera marina*

*** Threatened and endangered species are designated by underlining.**

SHORELINE DESCRIPTIONS

EXPOSED ROCKY SHORES **ESI = 1A**

DESCRIPTION

- The intertidal zone is composed of bedrock, steep (greater than 30° slope), and thus very narrow
- Sediment accumulations are uncommon because waves remove the debris that has slumped from the eroding cliffs
- They are regularly exposed to wave action and strong currents
- Attached organisms are accustomed to the impacts of the waves and the associated hydraulic pressure
- There is strong vertical zonation of intertidal biological communities; Species density and diversity vary greatly, but barnacles, snails, mussels, and macroalgae dominate
- They are common throughout the area along headlands and offshore islands wherever there is open fetch facing the direction of storm-generated winds

PREDICTED OIL BEHAVIOR

- Oil is held offshore by waves reflecting off the steep, hard surfaces
- During calm conditions, the oil can form a band at the high-tide line; oil will not adhere to wet, algae-covered surfaces
- Oil that is deposited is rapidly removed from exposed faces
- The most persistent oil would remain as a patchy band at or above the high-tide line
- Impacts to intertidal communities are expected to be short-term in duration.

RESPONSE CONSIDERATIONS

- Cleanup is usually not required
- Access can be difficult and dangerous

EXPOSED WAVE-CUT PLATFORMS IN BEDROCK **ESI = 2A**

DESCRIPTION

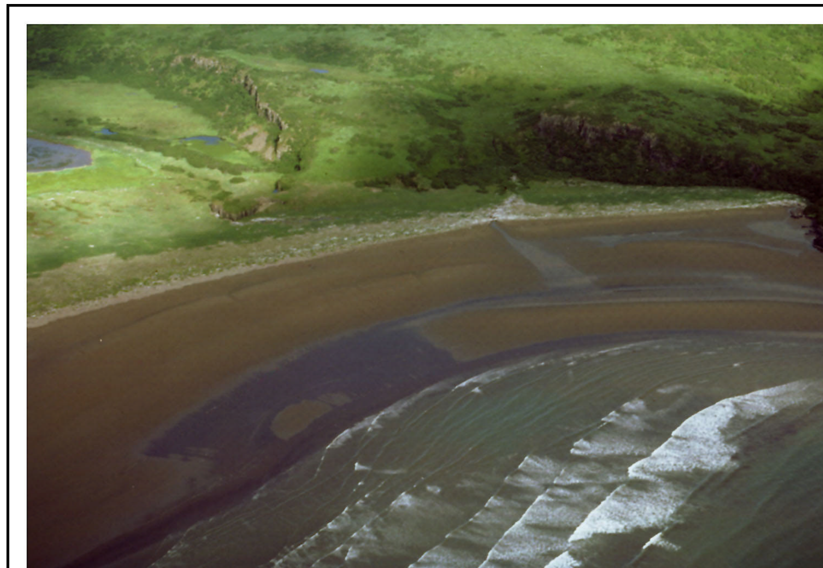
- These shores consist of a bedrock shelf or platform of variable width (up to hundreds of meters wide) and very gentle slope
- The surface of the platform is irregular and the presence of tidal pools is common
- The shoreline may be backed by a steep rock scarp or low bluffs
- There may be a narrow gravel beach at the base of the scarp
- Species density and diversity varies greatly, but barnacles, snails, mussels, and macroalgae are often very abundant
- Attached organisms are accustomed to the impacts of the waves and the associated hydraulic pressure
- They are common along the southern Alaska Peninsula and Sanak Island area

PREDICTED OIL BEHAVIOR

- Oil will not adhere to the wet rock surface, but could penetrate crevices or sediment accumulations if present
- Persistence of oil on the platform itself is usually short-term, except in wave shadows or where the oil was deposited high above normal wave activity

RESPONSE CONSIDERATIONS

- Cleanup is usually not required
- Where the high-tide area is accessible, it may be feasible to manually remove heavy oil accumulations and oiled debris
- Consider potential impacts to rich biological communities on the platforms when cleaning adjacent gravel beaches



FINE- TO MEDIUM-GRAINED SAND BEACHES **ESI = 3A**

DESCRIPTION

- These beaches are flat to moderately sloping and relatively hard packed
- They are composed of predominantly quartz sand
- They are utilized by birds for resting and foraging
- Backshore habitats include dunes and wetlands which are important seasonally as nesting areas for birds
- They are very uncommon, occurring at the heads of coastal bays along the southern Alaska Peninsula

PREDICTED OIL BEHAVIOR

- Light oil accumulations will be deposited as oily swashes or bands along the upper intertidal zone
- Heavy oil accumulations will cover the entire beach surface; oil will be lifted off the lower beach with the rising tide
- Maximum penetration of oil is about 10-15 cm
- Burial of oiled layers by clean sand within the first week after a spill typically will be less than 30 cm at the upper beach face
- Biological impacts include temporary declines in infauna, which can affect important shorebird foraging areas

RESPONSE CONSIDERATIONS

- These beaches are among the easiest shoreline types to clean
- Cleanup should concentrate on removing oil and oily debris from the upper swash zone once oil has come ashore
- Traffic through both oiled and dune areas should be limited, to prevent contamination of clean areas
- Manual cleanup is advised to minimize the volume of sand removed from the shore and requiring disposal
- All efforts should focus on preventing the mixture of oil deeper into the sediments by vehicular and foot traffic
- Mechanical reworking of lightly oiled sediments from the high-tide line to the lower intertidal zone can be effective in speeding natural recovery without having to remove sediment

COARSE-GRAINED SAND BEACHES ESI =4

DESCRIPTION

- These beaches are wide and have relatively steep beach faces and soft substrates
- They can undergo rapid erosion / deposition cycles, even within one tidal cycle
- They are utilized by birds and mammals for resting and foraging
- Backshore habitats include dunes and wetlands, which are important seasonally as nesting areas for birds
- They are very common along Bristol Bay; in other areas they occur at the heads of coastal bays and at stream mouths

PREDICTED OIL BEHAVIOR

- Light oil accumulations will be deposited as oily swashes or bands along the upper intertidal zone
- Heavy oil accumulations will cover the entire beach surface; oil will be lifted off the lower beach with the rising tide
- Maximum penetration of oil is about 20 cm
- Burial of oiled layers by clean sand within the first week after a spill can be up to 50 cm at the upper beach face
- Biological impacts include temporary declines in infauna, which can affect important shorebird foraging areas

RESPONSE CONSIDERATIONS

- Coarse sand sediments are less trafficable, increasing the risk of moving oil into the substrate by foot and vehicular traffic
- Cleanup should concentrate on removing oil and oily debris from the upper swash zone once oil has come ashore
- Traffic through both oiled and dune areas should be limited, to prevent contamination of clean areas
- Manual cleanup is advised to minimize the volume of sand removed from the shore and requiring disposal
- All efforts should focus on preventing the mixture of oil deeper into the sediments by vehicular and foot traffic
- Mechanical reworking of lightly oiled sediments from the high-tide line to the lower intertidal zone can be effective in speeding natural recovery without having to remove sediment

MIXED SAND AND GRAVEL BEACHES ESI = 5

DESCRIPTION

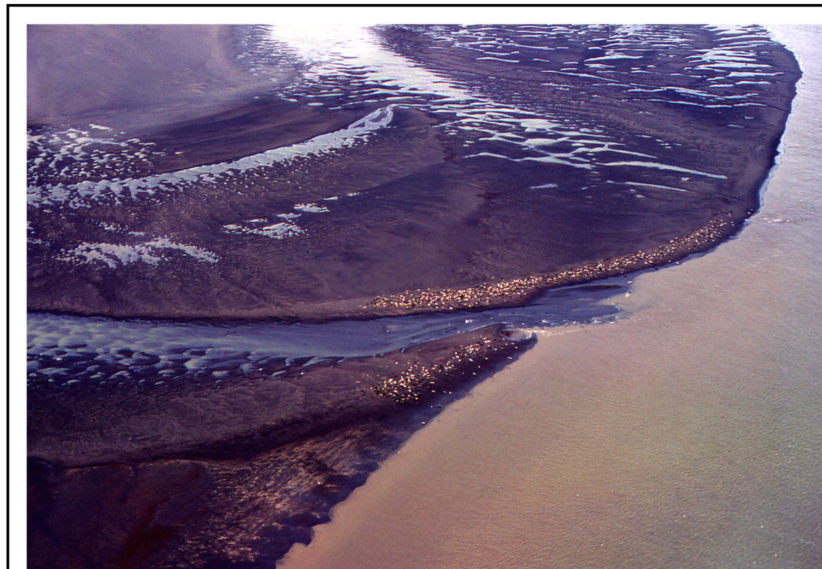
- Moderately sloping beach composed of a mixture of sand and gravel on the surface
- Because of the mixed sediment sizes, there may be zones of pure sand, pebbles, or cobbles
- There can be large-scale changes in the sediment distribution patterns depending upon season, because of the transport of the sand fraction offshore during storms
- Because of sediment desiccation and mobility on exposed beaches, they have relatively low densities of animals and plants; densities are higher for sheltered beaches
- They are the common shoreline type along the mapped Aleutian Islands and southern Alaska Peninsula, occurring as extensive beaches at the base of rocky cliffs, as perched beaches on rocky platforms, and along bays

PREDICTED OIL BEHAVIOR

- Oil penetration into the sediments may be up to 50 cm; however, the sand fraction can be quite mobile, and oil behavior is much like on a sand beach if the sand fraction exceeds 40 percent
- Burial of oil may be deep at and above the high-tide line, where oil tends to persist, particularly where beaches are only intermittently exposed to waves
- In sheltered pockets, pavements of asphalted sediments can form if there is no removal of heavy oil accumulations, because most of the oil remains on the surface
- Once formed, these asphalt pavements can persist for years
- Oil can be stranded in the coarse sediments on the lower part of the beach, particularly if the oil is weathered or emulsified

RESPONSE CONSIDERATIONS

- Heavy accumulations of pooled oil should be removed quickly from the upper beachface
- Sediment removal should be limited as much as possible
- Even low-pressure flushing should be avoided because of the potential for transporting contaminated sand to the lower intertidal or subtidal zones
- In-place tilling may be used to reach deeply buried oil layers in the middle zone on exposed beaches
- Mechanical reworking of oiled sediments from high tide to the upper intertidal zone (not below the mid-tide zone) can be effective in areas regularly exposed to wave activity (as evidenced by storm berms).



GRAVEL BEACHES ESI = 6A

DESCRIPTION

- Gravel beaches can be very steep, with multiple wave-built berms forming the upper beach
- The grain size of the gravel can vary widely, from small pebbles to large boulders
- Exposure to wave energy is highly variable. Degree of exposure can be inferred partly by the roundness/angularity of the gravel: well rounded gravel indicates regular re-working of the surface sediments by waves; angular gravel indicates infrequent exposure to waves big enough to re-work the sediments
- Density of animals and plants in the upper intertidal zone is low along exposed beaches, but can be very high on sheltered beaches and on the lower intertidal zone of all beaches
- Gravel beaches are a common shoreline type in the study area

PREDICTED OIL BEHAVIOR

- Deep penetration of stranded oil is likely on gravel beaches because of their high permeability
- Long-term persistence will be controlled by the depth of routine reworking by the waves; oil can persist for longer than 10 years
- Chronic sheening and the formation of asphalt pavements is likely where accumulations are heavy

RESPONSE CONSIDERATIONS

- Heavy accumulations of pooled oil should be removed quickly from the upper beachface
- Oiled debris should be removed
- Sediment removal should be limited as much as possible
- Low-pressure flushing can be used to float oil away from the sediments for recovery by skimmers or sorbents. High-pressure spraying should be avoided because of the potential for transporting contaminated finer sediments (sand) to the lower intertidal or subtidal zones
- Mechanical reworking of oiled sediments from high tide to the upper intertidal zone (not below the mid-tide zone) can be effective in areas regularly exposed to wave activity (as evidenced by storm berms).
- In-place tilling may be used to reach deeply buried oil layers in the middle zone on exposed beaches

RIPRAP ESI = 6B

DESCRIPTION

- Riprap structures are composed of boulder-sized blocks
- Riprap structures are used for shoreline protection and as breakwaters in marinas
- Attached biota are highly variable, depending on the elevation of the riprap
- They are present only in developed areas around shipping ports

PREDICTED OIL BEHAVIOR

- Deep penetration of oil between the blocks is likely
- Oil adheres readily to the rough surfaces of the blocks
- Uncleaned oil can cause chronic leaching until the oil hardens

RESPONSE CONSIDERATIONS

- When the oil is fresh and liquid, high-pressure spraying and/or water flooding may be effective, making sure to recover all liberated oil
- Heavy and weathered oils are more difficult to remove, requiring scrapping and/or hot-water spraying

EXPOSED TIDAL FLATS ESI = 7

DESCRIPTION

- Exposed tidal flats are broad intertidal areas composed primarily of sand and gravel
- The presence of sand indicates that tidal currents and waves are strong enough to mobilize the sediments
- Biological utilization can be very high, with large numbers of infauna, heavy use by birds for roosting and foraging, by mammals as haulouts, and use by foraging fish
- They are usually located inside of bays and lagoons, near the mouths of inlets where the currents are strongest

PREDICTED OIL BEHAVIOR

- Oil does not usually adhere to the tidal flat surface, but rather moves across the flat and accumulates at the high-tide line
- Deposition of oil on the flat may occur on a falling tide if concentrations are heavy
- Oil does not penetrate water-saturated sediments
- Biological damage may be severe, primarily to infauna, thereby reducing food sources for birds and other predators

RESPONSE CONSIDERATIONS

- Currents and waves can be very effective in natural removal of the oil
- Cleanup is very difficult (and possible only during low tides)
- The use of heavy machinery should be restricted to prevent mixing of oil into the sediments

SHELTERED ROCKY SHORES — ESI = 8A

DESCRIPTION

- The substrate is solid and composed of bedrock, although cracks and crevices can be common
- This shoreline type is sheltered from significant wave activity and strong currents
- Sheltered rocky shores often co-occur with gravel beaches at the lower half of the intertidal zone
- They are usually heavily encrusted with algae, barnacles, mussels, snails, limpets, and other attached animals and plants
- Intertidal habitats can be rich and diverse, supporting many different users (birds, fish, shellfish, mammals)
- They are uncommon, occurring only inside of bays and coves

PREDICTED OIL BEHAVIOR

- Oil tends to adhere to the upper intertidal zone where the rock surface dries out during low tide, and the algal cover is sparse
- On solid bedrock surfaces, the oil will occur as a surface coating
- Oil will penetrate and persist in crevices and sediment accumulations
- Stranded oil will persist because of low energy setting, particularly on the undersides of rock outcrops and in sediment accumulations

RESPONSE CONSIDERATIONS

- Thick accumulations of pooled oil should be of high priority for removal, to prevent re-mobilization and / or penetration
- Manual removal of heavy oil is likely to leave significant residues, but may be useful for oil in crevices or sediment pockets
- Flushing techniques will be most effective when oil is still fresh and liquid; restrict operations to tidal levels that will prevent oily effluents from impacting lower tidal elevations with rich intertidal communities
- Expect to increase temperature and pressure over time as the oil weathers; Evaluate trade-offs between oil removal and pressure / temperature impacts on intertidal communities
- Consider potential impacts to rich biological communities on the rocky shores when conducting cleanup of associated gravel beaches

SHELTERED TIDAL FLATS — ESI = 9A

DESCRIPTION

- Sheltered tidal flats are composed primarily of mud with minor amounts of sand and gravel
- They are present in low-energy habitats, sheltered from waves and currents
- The sediments are very soft and cannot support even light foot traffic in many areas
- There can be large concentrations of shellfish, polychaetes, and snails on and in the sediments
- They are heavily utilized by birds and mammals for feeding and resting
- They occur at the heads of bays and lagoons, away from the influence of strong currents and wave action

PREDICTED OIL BEHAVIOR

- Oil does not usually adhere to the surface of sheltered tidal flats, but rather moves across the flat and accumulates at the high-tide line
- Deposition of oil on the flat may occur on a falling tide if concentrations are heavy
- Oil will not penetrate the water-saturated sediments, but could penetrate burrows and desiccation cracks or other crevices in muddy sediments
- In areas of high suspended sediments, sorption of oil can result in deposition of contaminated sediments on the flats
- Biological damage may be severe

RESPONSE CONSIDERATIONS

- These are high-priority areas necessitating the use of spill protection devices to limit oil-spill impact; deflection or sorbent booms and open water skimmers should be used
- Cleanup of the flat surface is very difficult because of the soft substrate; many methods may be restricted
- Low-pressure flushing and deployment of sorbents from shallow-draft boats may be attempted

SALT- AND BRACKISH-WATER MARSHES — ESI = 10A

DESCRIPTION

- Width of the marsh varies, from a narrow fringe along lagoons toextensive areas at stream mouths, though most marshes are small in area
- Sediments are composed of mixtures of mud, sand, and gravel
- Resident flora and fauna are abundant with numerous species and high utilization by birds, fish, and shellfish
- They are generally widely scattered; extensive marshes are associated with Izembek Lagoon, Nelson Lagoon, and Mud Bay

PREDICTED OIL BEHAVIOR

- Oil adheres readily to intertidal vegetation
- The band of coating will vary widely, depending upon the water level at the time oil slicks are in the vegetation. There may be multiple bands
- If the vegetation is thick, heavy oil coating will be restricted to the outer fringe, although lighter oils can penetrate deeper
- Medium to heavy oils do not readily adhere to or penetrate the fine sediments, but can pool on the surface or in burrows
- Light oils can penetrate the top few centimeters of sediment and deeply into burrows and cracks (up to one meter)

RESPONSE CONSIDERATIONS

- Natural removal processes and rates should be evaluated prior to conducting cleanup
- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing. During flushing, care must be taken to prevent transporting oil to sensitive areas down slope or along shore
- Cleanup activities should be carefully supervised to avoid damage
- Any cleanup activity must not mix the oil deeper into the sediments. Trampling of the roots must be minimized
- Cutting of oiled vegetation should only be considered when other resources present are at great risk from leaving the oiled vegetation in place